fastNLO, NNLO-Bridge, Alpos

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(with a lot of input from Daniel Britzger)

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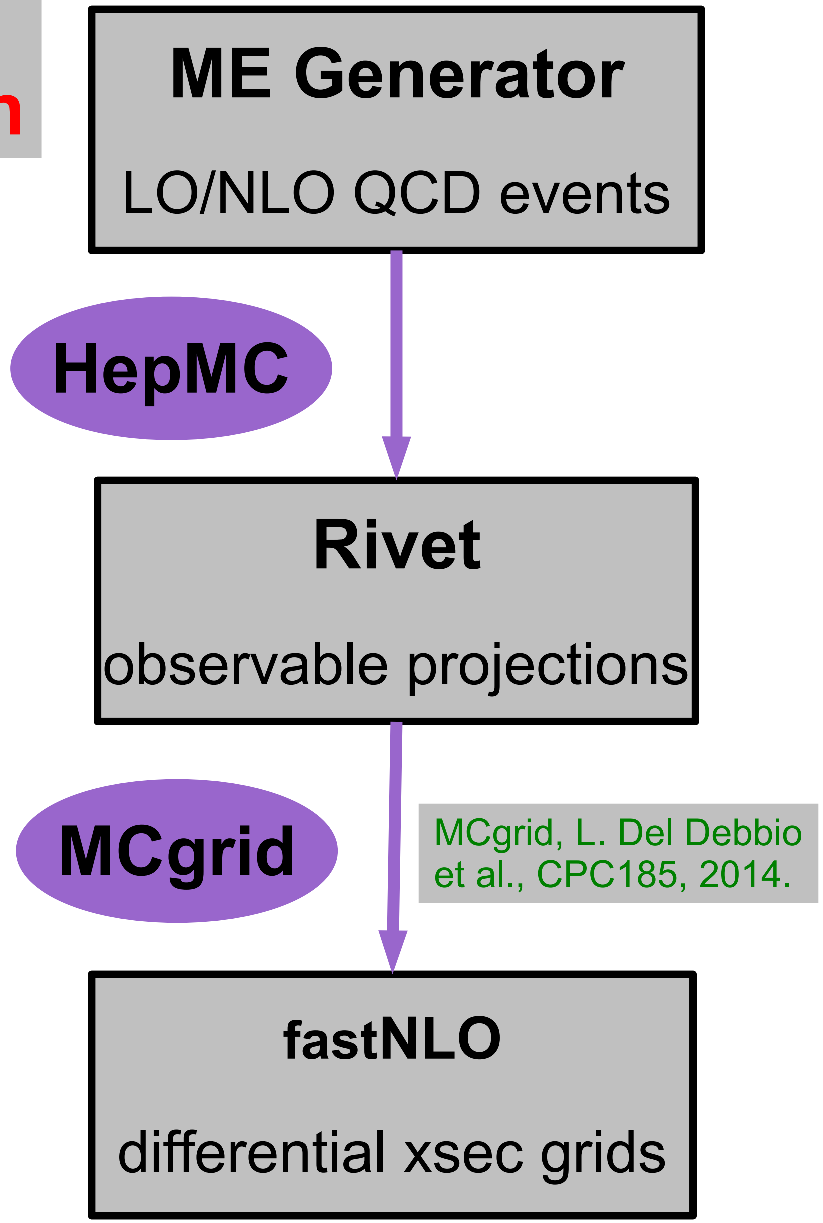
fastNLO development for xFitter

- fastNLO adapted to unified 'expression' interface for fastNLO & APPLgrid
- fastNLO part updated to latest version
- Removed specialities from old fastNLO interface code in HERAFitter
- xFitter part now almost identical to separate fastNlo

fastNLO with Sherpa2 & MCgrid2

In collaboration with Enrico Bothmann & Steffen Schumann

- **fastNLO Toolkit access implemented:**
  - **Events generated with Sherpa 2.1.1/2.2.0**
  - **MCgrid 2.0 for cross section projection into grids (to be released)**
- **Previous MCgrid version works in very similar way with APPLGRID**
  - **So ...**



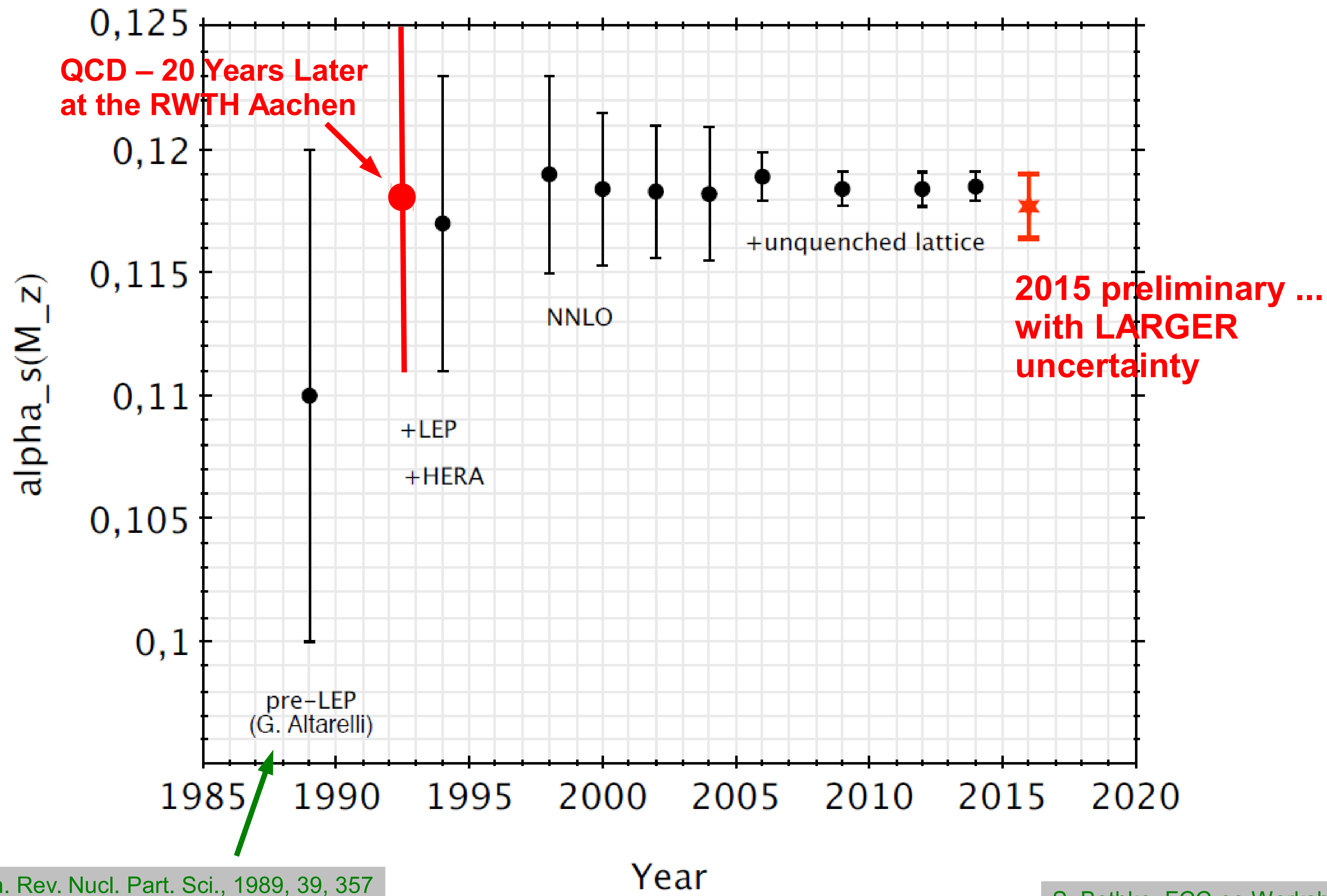
NNLO-Bridge

- Fruitful discussion last September in London during QCD@LHC between:
  - NNLO Theory: Nigel Glover, Tom Morgan, Joao Pires
  - APPLGRID: Mark Sutton, Claire Gwenlan
  - fastNLO: Daniel Britzger, KR
- Agreed to proceed towards common interface, NNLO-Bridge, to fill interpolation grids
  - Start and test setup with Z+jet process provided by Tom in their desired code structure
  - Jets @ NNLO to be restructured somewhat on theory side
- Mark prepared initial setup discussed via Skype meetings till November
- On hold since then, KR had to prioritize other duties :-(
- Urgently need to take up this thread again to make some progress …

Some Slides on α_s

- Some considerations on one of Mandy's fundamental constants
- The CMS jet analysis shown yesterday by Ringaile also contained combined fit of PDFs & α_s (done by G. Sieber)
- Least precisely known fundamental constant
- Ongoing disputes
  - Value and precision from lattice gauge theory
  - FOPT vs. CIPT debate in tau decays
  - Lowish vs. highish value ...
- Some slides (KR) updated from FCC workshop on α_s …

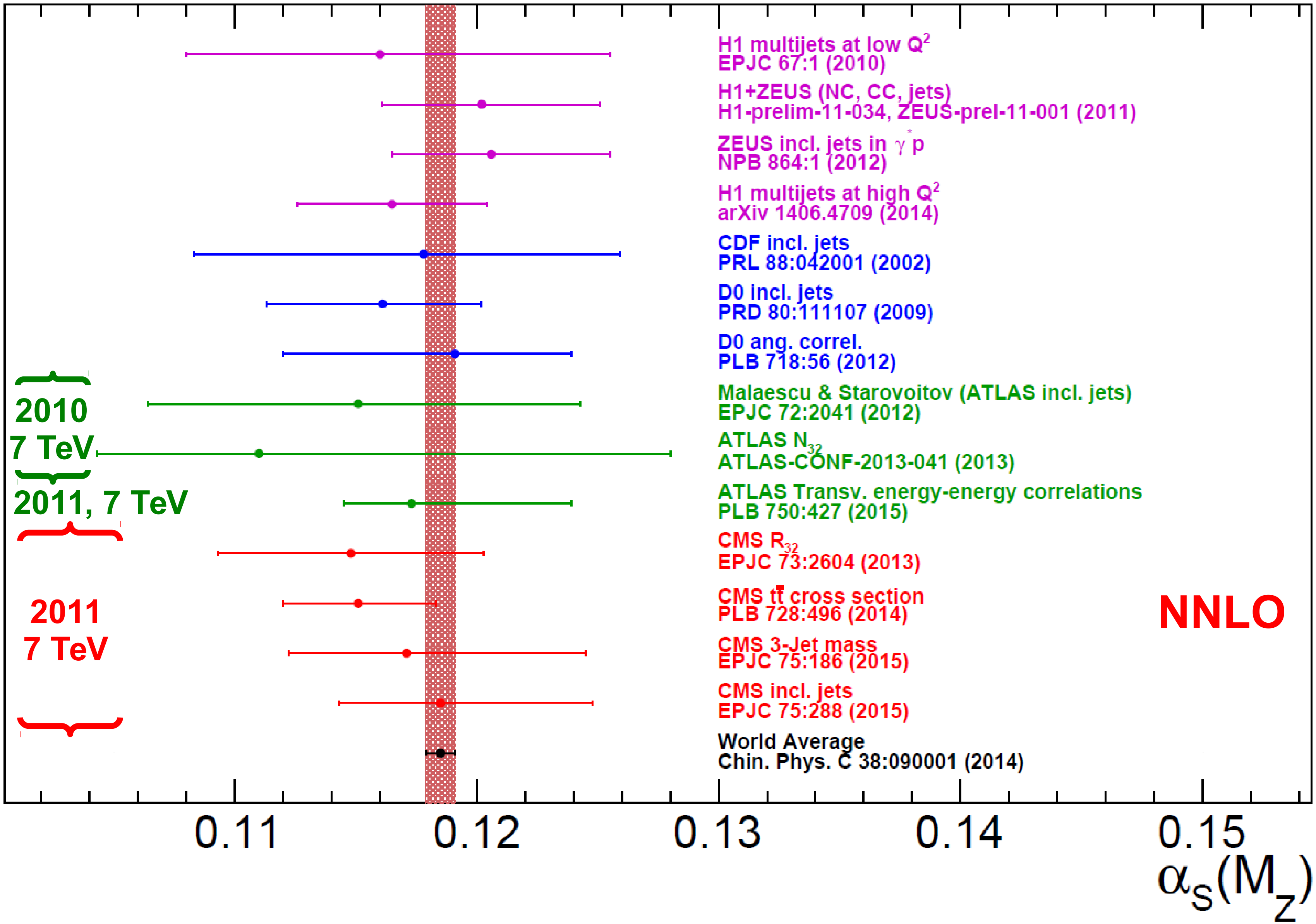
History of World Average of α_s



G. Altarelli, Ann. Rev. Nucl. Part. Sci., 1989, 39, 357

S. Bethke, FCC-ee Workshop

α_s @ Hadron Colliders



$\Delta\alpha_S / \alpha_S$ / %

exp	PDF	scale
1.2	1.4	8.0
no final publ.		
1.9	1.9	2.5
0.7	0.8	3.1
7.5	5.0	5.0
2.9	1.0	2.5
0.7	1.2	5.5
4.3	1.8	3.8
no final publ.		
0.9	1.4	5.4
1.2	1.6	4.4
2.2	1.5	0.7
1.1	2.0	5.9
1.6	2.4	4.5

Current Status

- LHC at 7 TeV and 8 TeV enables measurements up to scales of 2 TeV
- 13 TeV data extend this considerably
- Theory at NNLO QCD + electroweak corrections are a must!
- Typical uncertainties on $\alpha_s(M_Z)$:
  - Experimental: ~ 1 – 2 %
  - PDF: ~ 1 – 2 %
  - Scale: 3 – 5 %
  - Nonpert. Effects: < 1 %
- Beyond CMS:
  - Combined fits of ATLAS & CMS (LHC) measurements
  - Combined fits of HERA, Tevatron, & LHC measurements
- CHALLENGE: Check running of $\alpha_s(Q)$ up to 5 TeV and determine $\alpha_s(M_Z)$ to 5 permille accuracy

Perspectives & Educated Guesses

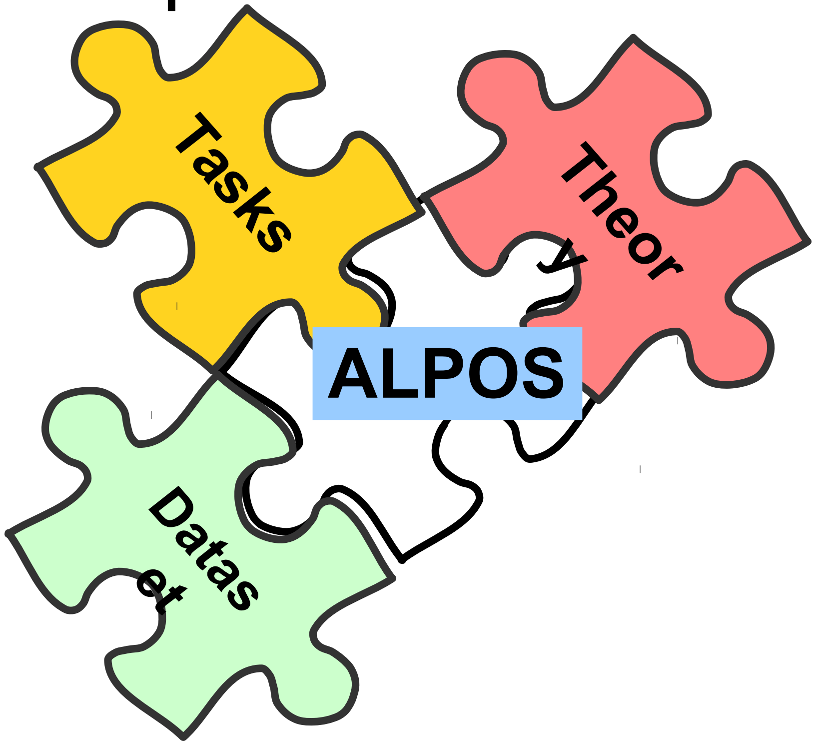
- **Experiment:**
  - **Done: Observables $\sigma \sim \alpha_s^2, \alpha_s^3$; $R_{3/2} \sim \alpha_s$; 7 TeV; full phase space**
  - **8 TeV data: Reduce experimental uncertainty by some permille?**
  - **Best JEC phase space: Another reduction by some permille?**
  - **Other observables: Ratios (n+m) / n jets (incl. γ, W, Z), $R_{\Delta\Phi}$, $R_{\Delta R}$ (→ D0) Normalized cross sections?**
- **Theory:**
  - **Scales: NNLO! → reduction by some percent!?**
  - **PDFs: Much improved after LHC I, also HERA 2 data available**
    - **Better known gluon (Attention circularity: jets → g(x) & jets → α_s)**
    - **Fits combining observables at various √s to disentangle g(x), M_t, α_s**

Alpos

C++-based tool for data-to-theory comparisons and fits

Every day's work

- Compare data to theory
- Judge about agreement
- Draw conclusions on
  - Theory parameters
  - Understanding of experimental uncertainties



Profit from and exchange with HERA/xFitter experience

Profit from C++ (heavily object-oriented design)

Well defined interface to 3 components: data, theory, tasks

Attractive to contribute for new students

Some Alpos Details

- Structured into three parts: 'theory', 'data', 'tasks', with caching for performance
- Flexible data specifications (asymmetric uncertainties, any number of uncertainties)
- Flexible and well-defined theory interface..
- Interfaces to Apfel, QCDNUM, fastNLO, APPLgrid, ...
- Multiple minimization algorithms:
  ROOT::Math::Minimizer: TMinuit, TMinuit2, GSL, ...
  Constrained least squares: APC, apccpp, aplcon (V. Blobel)
- Many chisq functions:
  'HERA', Covariance matrices, LogNormal (H1), D0-style, etc...
- Different PDF parameterisations (as in HERAFitter: HERA-style, BiLog, ...)
- Multiple tasks:
  Chisq calculations, minimizations, parameter scans, contour plots

HERAPDF1.0 fit

PDF fit of type HERAPDF1.0

- Use QCDNUM for structure functions (ZMVFNS)
- Use QCDNUM for PDF evolution

```
$ ./src/alpos tutorial/6.herapdf10.str
```

```
InitFunctions {{
    FunctionName          FunctionType
    QcdnumInit            QcdnumInit
    PDFQ0_HERA_10pts      PDFQ0_HERA_10pts
    QcdnumPDF             QcdnumPDF           # needed for 'SavePDF'
}}
```

```
QcdnumDISCS.QcdnumInit                    QcdnumInit # PDF, alpha_s is provided through QCDNUM
QcdnumDISCS.Mw                            80.385
```

QCDNUM is a fortran program

- No object-orientetd
- Solution: One singleton 'function' QcdnumInit
- QcdnumInit is input function to other functions around QCDNUM
  - QcdnumPDF
  - QcdnumAs
  - QcdnumDISCS

Alpos

```
MIGRAD MINIMIZATION HAS CONVERGED.
 FCN=599.113 FROM MIGRAD    STATUS=CONVERGED    1013 CALLS     1014 TOTAL
                     EDM=3.99026e-06    STRATEGY= 1  ERROR MATRIX UNCERTAINTY   0.5 per cent
  EXT PARAMETER                                   STEP         FIRST
  NO.   NAME        VALUE           ERROR         SIZE       DERIVATIVE
   1  PDFQ0_HERA_10pts.gB   3.15870e-01   3.26536e-02   1.12029e-04   1.14505e+00
   2  PDFQ0_HERA_10pts.gC   9.41984e+00   7.00901e-01   2.88391e-03  -8.52656e-02
   3  PDFQ0_HERA_10pts.uvB   7.06652e-01   1.85413e-02   2.83958e-05   2.05594e+00
   4  PDFQ0_HERA_10pts.uvC   5.12802e+00   2.42370e-01  -5.04500e-04  -2.39463e-01
   5  PDFQ0_HERA_10pts.uvE   1.05656e+01   2.27037e+00  -1.11086e-03   2.61973e-02
   6  PDFQ0_HERA_10pts.dvC   4.58635e+00   3.73857e-01   1.26045e-03  -6.57842e-02
   7  PDFQ0_HERA_10pts.UbarC   1.33662e+00   1.88350e-01   5.33714e-04  -1.14586e-01
   8  PDFQ0_HERA_10pts.DbarA   1.13812e-01   3.84916e-03  -4.22832e-07  -5.24836e+00
   9  PDFQ0_HERA_10pts.DbarB  -2.13218e-01   4.63145e-03  -2.60368e-06   5.64812e+00
  10  PDFQ0_HERA_10pts.DbarC   2.82604e+00   7.80673e-01  -1.95571e-03  -5.93404e-02
```

HERAFitter

```
MIGRAD WILL VERIFY CONVERGENCE AND ERROR MATRIX.
COVARIANCE MATRIX CALCULATED SUCCESSFULLY

FCN=   599.0083      FROM MIGRAD    STATUS=CONVERGED   1091 CALLS    1094 TOTAL
                     EDM=  0.92E-05    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                      STEP         FIRST
 NO.    NAME        VALUE          ERROR           SIZE       DERIVATIVE
  2     Bg         0.31589       0.32342E-01    0.33667E-04   -1.0115
  3     Cg          9.4195       0.68932        0.49584E-03   0.71943E-01
 12     Buv        0.70666       0.18317E-01    0.20803E-04   -1.8531
 13     Cuv         5.1276       0.24026        0.17813E-03   0.22745
 15     Euv        10.564         2.2212        0.16083E-02  -0.24652E-01
 23     Cdv         4.5884       0.37389        0.66150E-03   0.55725E-01
 33     CUbar       1.3370       0.19037        0.36544E-03   0.10098
 41     ADbar      0.11380       0.38530E-02    0.58487E-05    6.1119
 42     BDbar     -0.21323       0.46307E-02    0.58352E-05   -6.0739
 43     CDbar       2.8255       0.75066        0.70510E-03   0.50264E-01
```

Also 'HERAPDF2.0' benchmark available

Sphinx based Documentation

Alpos Documentation

Alpos is an object-oriented data to theory comparison and fitting tool

The project homepage is found at http://www.desy.de/~britzger/alpos/

Growing documentation for newcomers in preparation

Tutorial with 8 examples exists

People welcome

Publically accessible svn repository

Local table of contents

Some Remarks

- Find Alpos also useful, because
  - Known problem, expertise lost when students leave
  - Multiple reinventions of X^2 and α_s fitting codes
  - In CMS at least four different codes used for α_s fits
  - Unify and conserve in form of Alpos tasks

Related Work

- Cannot show any result, D.Haitz & G. Sieber show their "private work" at the German Phys. Soc. Meeting beg. of March, Hamburg
- PhD work of Dominik Haitz:
  - JEC & 8 TeV Z(→ ee) +jet |y| & pT distributions, NLO theory from BlackHat/Sherpa/MCgrid/fastNLO, PDF fits with xFitter
- PhD work of Georg Sieber:
  - 8 TeV dijet measurement, NLO theory from NLOJet++/fastNLO, PDF fits with xFitter
- PhD student from India:
  - X^2 comparisons of data vs. theory with xFitter & Alpos (matched)
- New master student Daniel Savoiu:
  - Developing & benchmarking Alpos, exactly reproduce H1 α_s fit (done), CMS (in progress), and D0 (To do) in Alpos
  - Combined fits, add ATLAS data into fit

Final Remarks

- Concentrated on α_s as fundamental parameter, of course correlated to i.a. gluon PDF …
- Alpos used for EW-parameter fit in H1
- More global fits conceivable in principle
- Combined effort required from experimenters, theorists, and tools developers

Many thanks to the Organizers of the Meeting

here in Dubna!

Thank you.

Backup Slides

α_s Uncertainties at Hadron Colliders

Process	LO	$\sqrt{s}$	Q	N_p	$\alpha_s(m_Z)$	$\Delta\alpha_s(m_Z)/\alpha_s(m_Z)$ [%]				
ep, $p\bar{p}$, pp	α_s^n	[TeV]	[GeV]			exp	PDF	scale	NP	other
H1 jets low Q^2	1	0.32	5–57	62	0.1160	1.2	1.4	8.0	scl	–
ZEUS γp jets	1	0.32	21–71	18	0.1206	1.9	1.9	2.5	0.4	–
H1 jets high Q^2	1	0.32	10–94	64	0.1165	0.7	0.8	3.1	0.7	–
CDF incl. jets	2	1.8	40–250	27	0.1178	7.5	5.0	5.0	–	2.5
D0 incl. jets	2	1.96	50–145	22	0.1161	2.9	1.0	2.5	1.1	–
D0 ang. corr.	1	1.96	50–450	102	0.1191	0.7	1.2	5.5	0.1	–
ATLAS incl. jets	2	7	45–600	42	0.1151	4.3	1.8	3.8	1.9	5.2
ATLAS EEC	1	7	250–1300	22	0.1173	0.9	1.4	5.4	0.2	–
CMS $R_{3/2}$	1	7	420–1390	21	0.1148	1.2	1.6	4.4	scl	–
CMS $\sigma(t\bar{t})$	2	7	M_t^{pole}	1	0.1151	2.2	1.5	0.7	–	1.1
CMS 3-jet mass	3	7	332–1635	46	0.1171	1.1	2.0	5.9	0.7	–
CMS incl. jets	2	7	114–2116	133	0.1185	1.6	2.4	4.5	0.3	–

Workshop Proceeedings:
arXiv: 1512.05194

Snippets of Rivet+MCgrid analysis

```
#include "Rivet/Analysis.hh”
#include "mcgrid/mcgrid.hh"
...
namespace Rivet {

  /// CDF Z boson rapidity modified to generate grid files
  class MCgrid_CDF_2009_S8383952 : public Analysis {
  public:
...
using namespace MCgrid;
Histo1DPtr _hist_yZ;  // Rivet histogram
gridPtr _grid_yZ;     // Corresponding grid

// Init phase
subprocessConfig subproc("DY-ppbar.str", BEAM_PROTON, BEAM_ANTIPROTON);
fastnloGridArch arch(50, 1, "Lagrange", "OneNode", "sqrtlog10", "linear");
fastnloConfig config(0, subproc, arch, 1960.0);
_hist_yZ = bookHisto1D(2, 1, 1);                       // Book Rivet
_grid_yZ = bookGrid(_hist_yZ, histoDir(), config);   // Book MCgrid/fastNLO

// Analyse phase
PDFHandler::HandleEvent(event, histoDir());  // Update subprocess statistics
_hist_yZ->fill(yZ, weight);                  // Fill Rivet
_grid_yZ->fill(yZ, event);                   // Fill MCgrid/fastNLO

// Finalise phase
scale(_hist_yZ, normalisation);              // Scale Rivet
_grid_yZ->scale(normalisation);              // Scale MCgrid/fastNLO
PDFHandler::CheckOutAnalysis(histoDir());    // Finalise
```

Setup Rivet with MCgrid

Book & config grid and histos

Fill events in event loop.

Final check out, normalize, write table.

Available Content

- Various datasets (~40-60)
  - ATLAS, CMS, H1, ZEUS, D0, CDF
  - PDG parameters: mt, mH, mW, ...
- Functions:
  - ApfelDISCS, ApfelAs, ApfelPDF, ApfelQEDEvol
  - QcdnumDISCS, QcdnumAs, QcdnumPDF
  - EPRC
  - CRunDec
  - fastNLO, fastNLOInterpol, fastNLOnormDIS
  - Applgrid
  - Lhapdf6, Lhapdf6Alphas
  - ...

Available Content

- **Tasks**
  - **AFitter, ApcFit, AApcalc, AConstLQFitter**
  - **StatAnalysis, Chi2Scan, Contour**
  - **PDFUncertainty, ScaleUncertainty**
  - **SavePDFTGraph,**
  - **PrintErrorSummary, PrintInputSteering**

Tasks

- Not discussing details on data or theory interface
- The expert: → Daniel Britzger, see also his talk in xFitter developers meeting
- Tasks are classes with simple, well-defined duties
  - Fits
  - Do some data-to-theory comparison
  - Write-out or print results (save PDFs or tables of fit-parameters)
  - Make contour plots
  - Calculate PDF uncertainties
  - Perform model tests
  - Do chisq scans
  - etc...

Tasks

- **Execution**
  - Tasks are specified in the steering
  - Execute one after the other ...
- **Concept**
  - Tasks have full access to all theory-parameters
  - Tasks have their own steering
  - Object-oriented approach: A task may be executed multiple times with different steering-parameters

Write out (fitted) PDF

- Task 'SavePDFTGraph'
  - Write out PDFs as TGraph into ROOT-File
  - Missing: Fitted PDF uncertainties not yet transformed into eigenvalues

- SavePDFTGraph
  - Specify scales muf in steering
  - Numerous flavor compositions
  - For each PDF set
  - Including uncertainty (for LHAPDF)